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(54) Apparatus for desalinating wat r by reverse osmosis

(57) In a reverse osmosis plant for desalinating seawater or brackish water the osmosis cell or cells (1) are located at a level sufficiently below the saline water supply (6) and the brine discharge point (8) so that the hydrostatic pressure resulting from head (2) provides the major compon nt of the pressure at the saline side of the osmosis cell or cells needed to bring about reverse osmosis. The osmosis cell or cells may be located about 500 metres underground and purified water pumped (9) from the cell or cells to the surface. By this means the power consumption of the plant is substantially less than that of a conventional reverse osmosis plant.

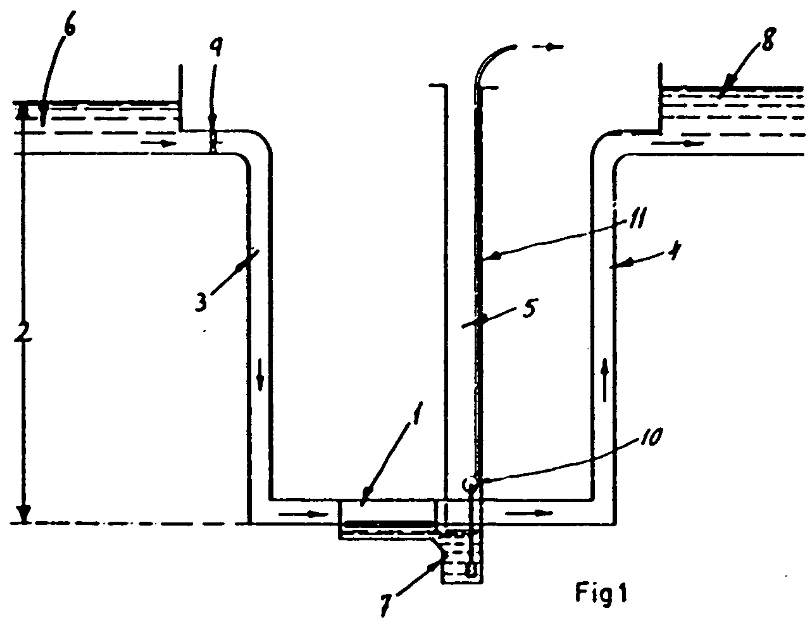

Fig 1

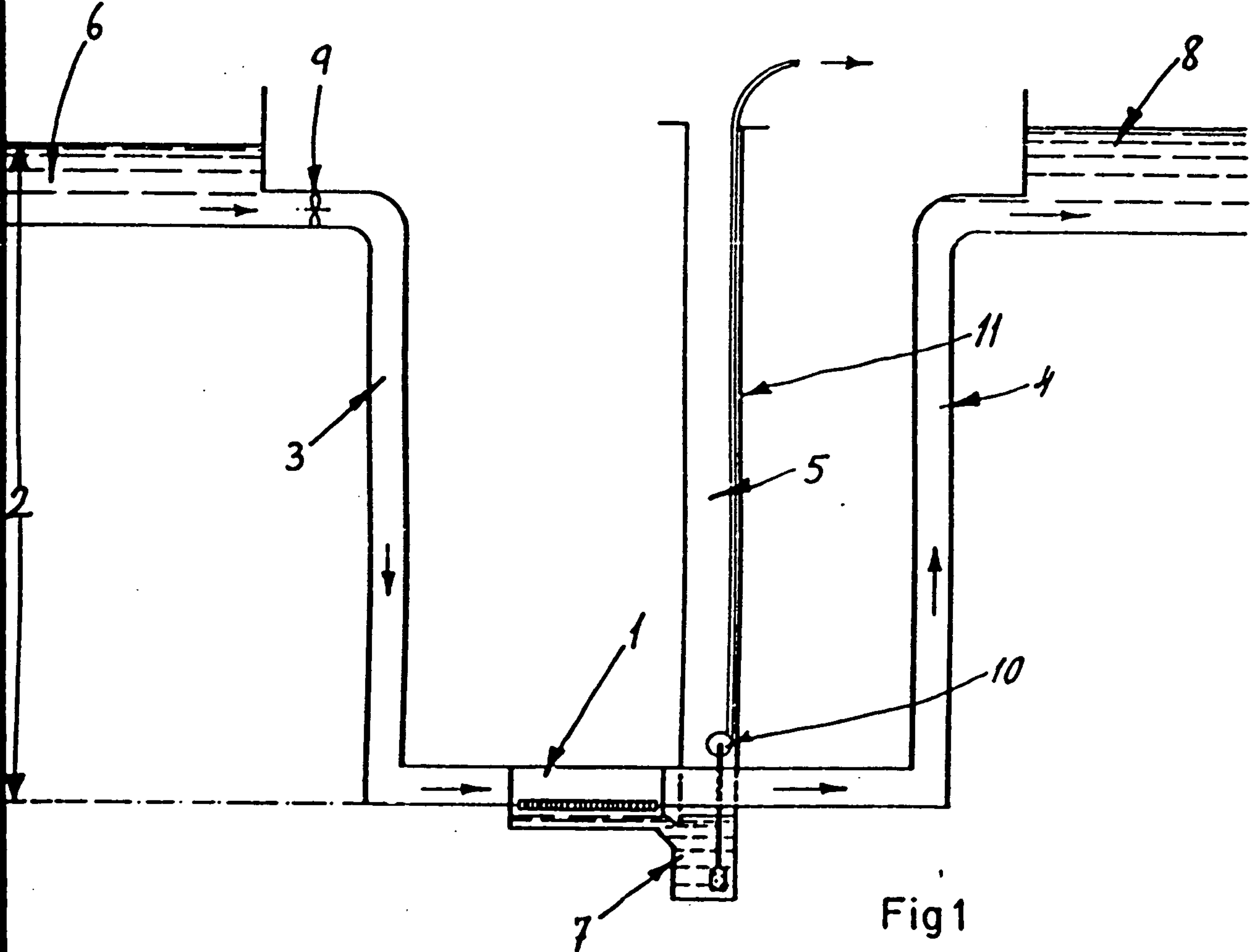

Fig1

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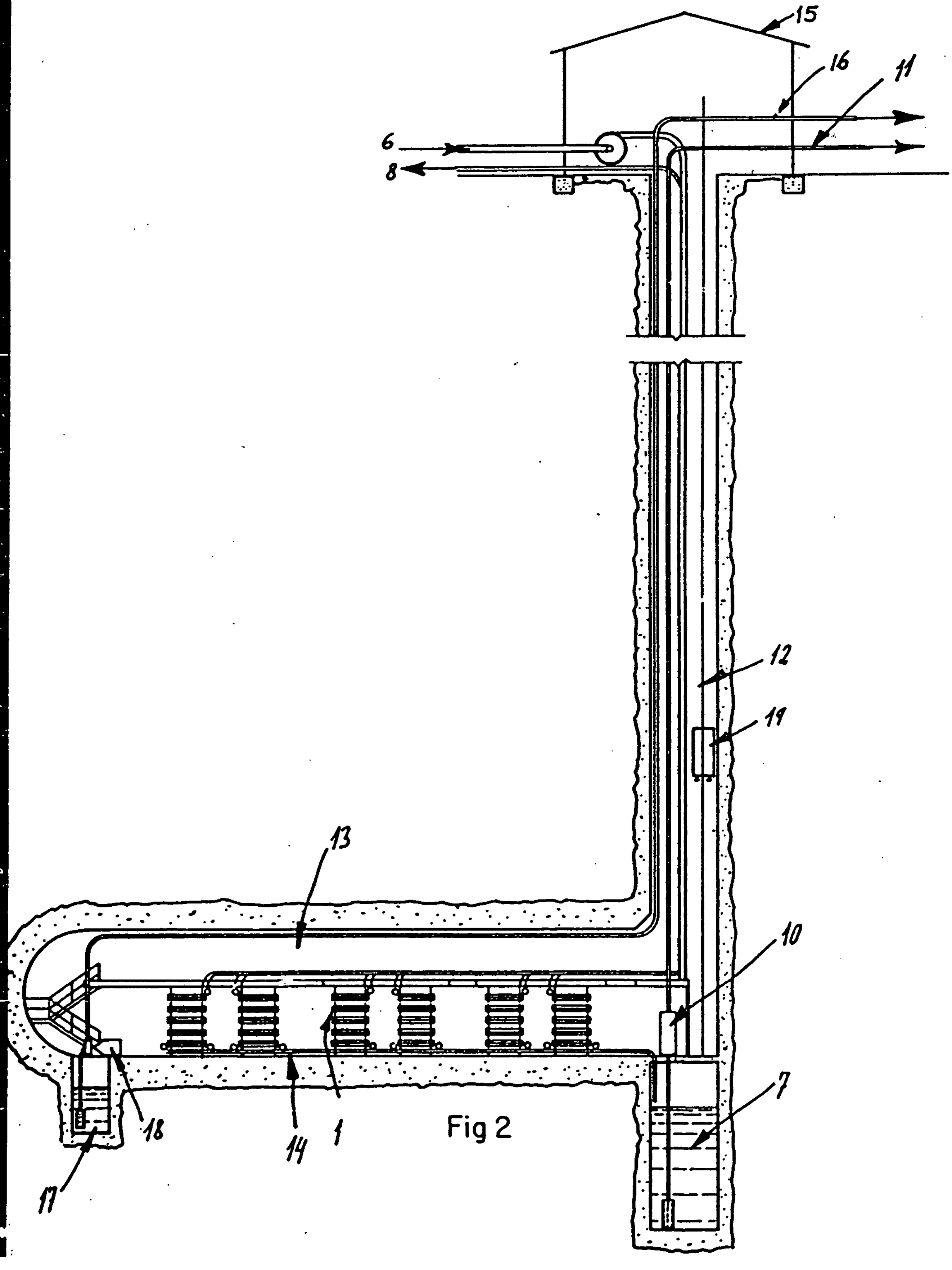

Fig 2

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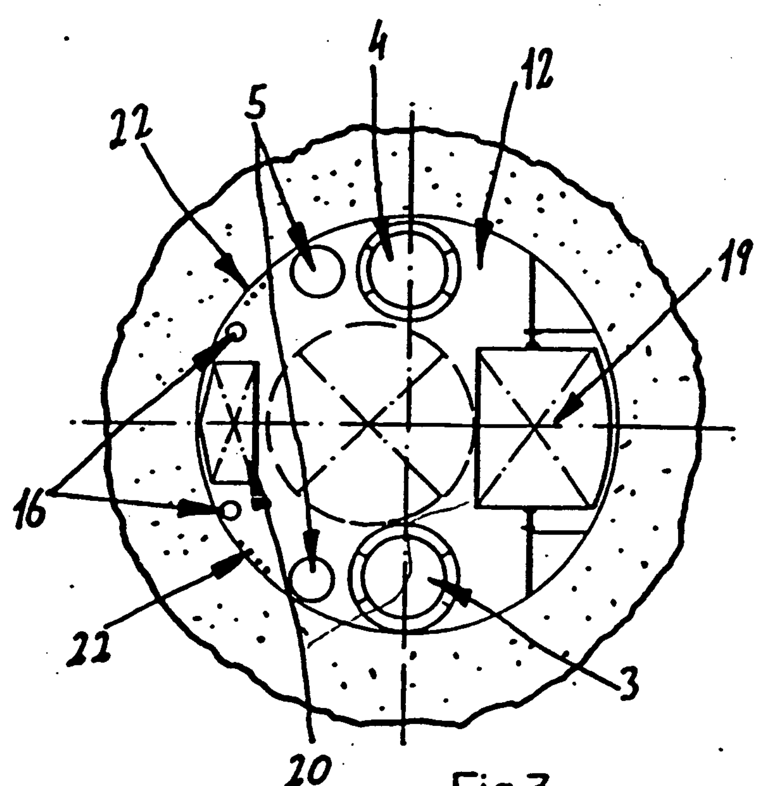

Fig 3

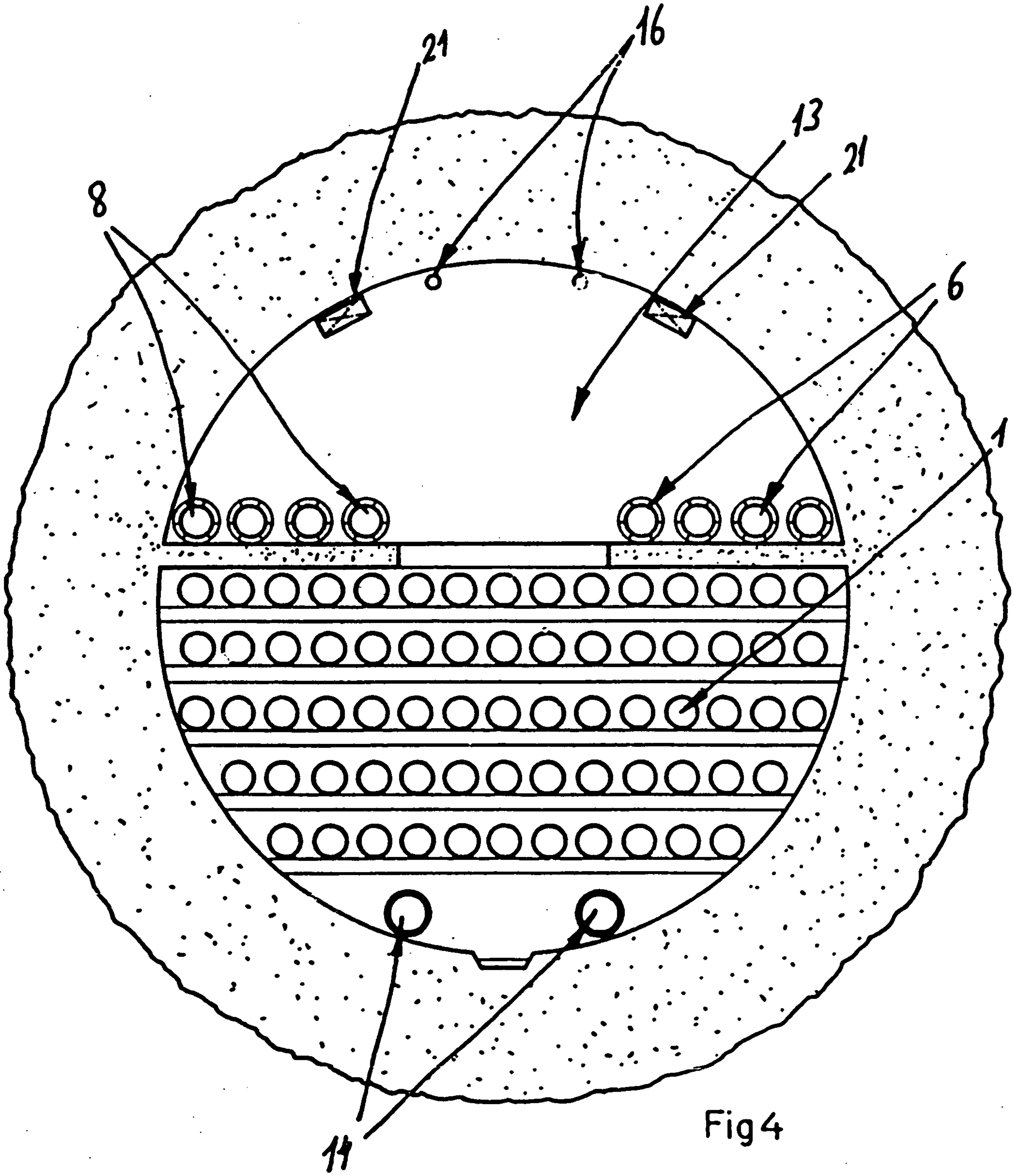

Fig 4

SPECIFICATION

Apparatus for desalinating water by rev rse smosis

This invention is concerned with a water desalting plant which operates by means of a reverse osmosis hydrostatic system.

It is very well known difficulty is created in many areas of the world by the scarcity of potable or fresh water, both for industrial and agricultural purposes and also to meet human needs. In many areas where there are substantially no supplies of fresh water, various systems are used to purify brackish water or seawater.

Until recently most processes employed for desalting seawater or brackish water are of thermal kind, but these inevitably have very high energy requirements. Thermodynamic calculations show that to obtain one cubic metre of fresh water from an infinite volume of seawater, the energy required cannot be less than 700 Kg. calories, i.e., 0.814 KwH, irrespective of the method use. Various thermal systems could in theory approach this efficiency if all steps of th process were always reversible, i.e., operated near to equilibrium. But to work in this way would mean a very slow rate of working which is in the realm of pure theory. In order to get a system which has a practical value, the rate of operation has to be accelerated, thus producing a great deviation from reversible equilibrium conditions and so a great increase in the power consumption. Water production by simple distillation has the highest power consumption among the thermic systems and the production of one cubic metre of fresh water requires 540,000 Kg calories.

A dual-purpose thermic-type seawater desalting plant which produces both potable water and electrical power requires about 100,000 Kg. calories per cubic metre of fresh water produced, which is attributable solely to the production of fresh water, but to this consumption must be added the energy used to generate electrical power.

Reverse osmosis desalination systems are better than thermal systems in their yield of fresh water per unit power consumed and can give a cubic metre of fresh water for a little as 4,000 Kg. calories. The practical performance for sea-water, at the present industrial level, is from 9,500 Kg. calories for small installations to 5,800 Kg. calories for major installations, with power being recovered from the waste water. But reverse osmosis has not until a few years ago been employed in the desalination of water for industrial use and especially not in the desalination of highly salin water like sea-water.

I have developed a desalting plant which works by revers osmosis and is capabl of working on an industrial scal under optimal conditions at a power consumption as low as about 2,300 kilocalories/cubic metre of fresh water.

This pow r saving, which approach s 50%, is v ry significant because it r duces the cost of desalinating water, but it is additionally significant in the present circumstances where nergy is scarce and costly. These factors will hav an adverse eff ct on th economics of operating conventional thermal systems which consume great quantities of petroleum derivates.

It is known that reverse osmosis desalination plants work by the physical phenomenon of osmostic pressure. If two vessels, one containing pure water and the other containing a saline solution, are communicated by means of a semi-permeable membrane, a flow of pure water into the vessel containing the solution takes place through this membrane. But if a pressure is applied to the vessel containing the solution, the inflow of water takes place at a reducing rate until the difference of pressure applied to the two liquids reaches a certain critical value which is a function of the solution's concentration and the liquid's absolute temperature, at which value the water inflow disappears. If the applied pressure exceeds this critical value, the phenomenon of reverse osmosis occurs, i.e. pure water now flows from the vessel which contains the solution to the vessel which contains the pure water.

If reverse osmosis is carried out at a constant temperature the minimum pressure necessary to maintain a flow of fresh water is proportional to the saline concentration. As pure water is separated from the saline solution, its concentration rises and so the applied pressure must be increased if the flow of desalted water is to be maintained. So if it is desired to obtain a continous flow of desalinated water at a certain pressure, it is necessary to feed fresh saline solution to the appropriate vessel and to purge the system by extracting the concentrated brine. Since the saline solution is under pressure, purging may be carried out by allowing the concentrated saline solution to flow away from the vicinity of the membrane through a flow control valve. In this way it is possible to control the maximal saline concentration and so regulate the working of the process. The conversion ratio of a reverse osmosis desalination process is expressed as the ratio of the volume of fresh water product to the volume of the feeding water. For seawater this ratio is usually situated between 15 and 30%.

The absolute power consumption of a reverse osmosis desalting plant is very much less than that of a thermal system, as has been said above. But the main power requirement of a reverse osmosis desalination plant is in feeding a relatively large volume of saline water under pressure to the membrane with only a minor proportion of the saline feed being converted to fresh water and the major proportion thereof being wasted as brine.

The reverse osmosis hydrostatic desalting plant which forms the subject-matter of this invention provides a substantial reduction in the power needed to feed saline water to th osmotic cells, which is where the major proporti n of the pow r is c nsumed.

The inv ntion provides an apparatus for d salinating water by r vers osmosis comprising a salin water supply and a brine discharg point at a first l vel, on or more osmotic c lls at a second level, first and second ducts respectively communicating a saline water inlet to the osmotic cell or cells nd a brin outlet thereof with th saline water supply and

the brine discharg point, a chamb r to which fresh water from th osmotic c ll or cells fl ws, and a delivery pipe for th fresh water from th chamb r, th height differ nce between th first and s cond levels being such that in operation the hydrostatic pressure exerted by the column of water on the saline side of the osmotic cell provides at least a major component of the pressure to bring about reverse osmosis.

A fundamental characteristic of the desalting plant is the use of hydrostatic methods to supply the necessary large volumes of salt water at high pressure to the or each osmotic cell, preferably by a subterranean location of the osmotic cell. Three vertical wells or ducts, which may reach a maximal depth of about 500m., communicate at their lowser ends with a working zone in which the reverse osmosis cell or cells are located. A seawater supply duct and a brine discharge duct communicate directly at their lower ends with the appropriate connections of a reverse osmosis cell, and the water pressure applied at the saline side of the cell is determined by the water column. The outlet for fresh water is collected in a low-level chamber at atmospheric pressure and is pumped to the surface.

From the above it is apparent that the power which is needed to obtain the appropriate pressure at the osmotic cell is minimal, since only a circulating pump is required, which displaces brine in the osmotic cell with fresh saline water. But since there is no height difference between the saline supply and brine discharge ducts, the fundamental power consumption is determined by a force pump which extracts the desalted water from its chamber and elevates it to the surface.

The osmotic cells are located at the lowest part of a U-duct which is at a sufficient depth under the surface level and through which the sea-water is circulated that the reverse osmosis process can take place. This hydrostatic method replaces the conventional process of reverse osmosis desalting where the whole volume of seawater to be treated has to be pumped at high pressure into the osmosis cell and the brine is discharged from the cell at atmospheric pressure, thereby wasting most of the power involved in the pumping. Although the claimed desalting plant also uses a force pump to raise the fresh water produced, its power consumption is considerably less than that needed to pump the salt water feed because the volume of fresh water is much less, typically only 30% of the volume of saline water feed.

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows an schematic vertical section of a hydrostatically operated revers osmosis desalinati n plant acc rding t th inventi n;

Figure 2 shows a practical embodiment of a hydrostatically operated rev rs osmosis desalination plant, also in v rtical section;

Figure 3 shows a cross-section of a downshaft or well which forms part of th plant shown in Figure 2; and

Figure 4 shows a section through the production lev l in th desalination pl nt sh wn in Figure 2.

In Figure 1, it can b observed that th desalination plant is fundamentally bas d on the disposition of th smotic cell or cells at a depth of about 500m., this osmotic cell 1 being communicated to th surface by means of three ducts or wells 3, 4 and 5. Th ducts 3 and 4 together form a U-shaped tube with the osmotic cell located in its central limb which is disposed at the lowest position. Salt water 6 descends through the tube 3 and reaches the osmotic cell, where a percentage of it (about 30% as has been previously said) crosses over the membranes as desalinated water and passes to an auxiliary chamber. The residual water, which has an enhanced salt concentration ascends through the duct 4 and reaches the discharge area 8 where it is discharged as brine. Since there is no difference in level between the salt water supply 6 and the area 8 where brine is discharged, displacement of wat r in ducts 3 and 4 to bring out the brine which is continuously being produced in the osmotic cell or cells requires minimal power. A circulating pump 9 can be located within the U-shaped tube 3, 4 at any point, but preferably it is located in the feed duct 3 wher the saline concentration is lesser and, consequently, attack by the salt on the pump will be of little importance. Despite this minimal power consumpti n feeding water to the osmotic cell 1, adequate pressure is obtained to bring about the reverse osmosis phenomenon from the height 2 of the column of water which is selected to be at an appropriate value. The desalted water produced is returned to th surface by means of a force pump 10 through a duct located within the third well 5. Obviously pow r is used to pump desalted water from the auxiliary chamber 7 depending on the value of height 2 but it is considerably smaller than that which would be needed to obtain adequate pressure on the supply side of the osmotic cell, if no difference of level 2 existed between this cell and the saline supply and brine discharge points 6 and 8.

The theoretical scheme shown in the Figure 1 can be put in practice according to Figure 2 in which a single down-shaft 12 contains the ducts 3, 4 and 5 corresponding respectively to salt water supply, brine discharge and fresh water discharge. At th bottom of this shaft 12 there is a side level 13 which contains the osmotic cells 1, whilst the auxiliary chamber containing the desalted water 7 is located underneath the downshaft 1 itself and duct 14 for delivering the fresh water produced communicates the discharge side of the osmotic cells 1 with the auxiliary chamber 7.

The circulating pump 9 is located inside a building 15 which covers the entrance of the well down shaft 12 and is fed with pretreated salt water through a duct 6. A duct 8 leads brine away as wast product and ther is als a duct 11 through which fresh wat r is delivered. A well at the bottom of th process level 13 collects filtered matter and ther impurities of s wage-lik nature and th s ar discharged by a force pump 18 thr ugh a duct 16.

The well down-shaft may additionally be provided with a freight l vator 19, a duct 20 (Figure 3) for th descent of ventilating air which extends to the pr - cess level 13, where it is denoted by reference num-

ral 21 (Figure 4) and an appropriate electrical wiring 22. It is also desirable that all the abov menti n d components should be located about the periph ry of the well down-shaft 12 so that ther is a larg central void through which large components can be transported between level 13 and the surface.

The pump 9 which circulates water through the saline feed and brine discharge circuit is located at the surface level within the building 15 because it is bulky and has to deliver a high water flow at relatively low pressure. It is also convenient to position the pump here because the pump pressure adds to the hydrostatic pressure and reduces by some metres the depth to which the well shaft has to be sunk in order to obtain the appropriate working pressure at the osmotic cell and hence the length of the ducts is also reduced.

In major production installations, the ducts for descent of the seawater 3 and for ascent of the brine 4 may be constituted by separate wells in which the well down-shaft itself operates as a duct. In this case, a central well down-shaft working at atmospheric pressure, would provide access to the underground equipment and to passages leading to other ducts and services.

In small plants, only a single well shaft is normally made which is not visitable during its operation. After the well shaft has been filed with seawater through its mouth, all the osmotic process is carried out by means of an umbilical duct which in its inside contains the ascent tubes for the brine and the desalted water, and which also communicates at atmospheric pressure with the osmotic cells located at the lower end of the duct. This last space serves also for the descent of the electrical wiring intended for feeding the pump or pumps.

From the above it is apparent that the fundamental advantage of the reverse osmosis hydrostatic system for desalinating water is its very low power consumption and although the working of the system has been described with reference to sea water it is apparent that it is also useful for waters with a higher degree of salinity.

CLAIMS

1. Apparatus for desalinating water by reverse osmosis comprising a saline water supply and a brine discharge point at a first level, one or more osmotic cells at a second level below the first level, first and second ducts respectively communicating a saline water inlet to the osmotic cell or cells and a brine outlet thereof with the saline water supply and the brine discharge point, a chamber to which fresh water from the osmotic cell or cells flows, and a delivery pipe for the fresh water from the chamber, the height difference between the first and second lev ls being such that in op ration th hydr static pressur xerted by the column of water on th saline sid of the smotic cell provides at least a maj r comp n nt of the pr ssure to bring ab ut revers osmosis.

2. Apparatus according to Claim 1, wherein the saline water supply and the brine discharg are at gr und lev l and the osmotic cell r cells are located und rground, a force pump b ing provid d to pump fresh water through the delivery pipe from an underground fresh water chamber to the surface.

3. Apparatus according to Claim 1 or 2, wherein the first duct is provid d at or near the first level with a circulating pump which d livers saline water at high volume and low pressure to cause a continuous inflow of saline water through the first duct to the osmotic cell or cells and a continuous outflow of brine the osmotic cell of the brine discharge point, the pressure to bring about reverse osmosis b ing derived additively from hydrostatic pressure and pump pressure.

4. Apparatus according to any preceding claim, wherein a single well shaft accomodates a saline supply duct, a brine riser duct and a fresh water riser duct and at the lower end of the well shaft are formed one or more side passages in which the osmotic cells are located.

5. Apparatus according to Claim 4, wherein fresh water conduits lead from the or each osmosis cell in the or each side passage to a fresh water collection chamber below the well shaft.

6. Apparatus according to Claim 4 or 5, wher in the well shaft is further provided with a freight elevator, a ventilating air downpipe and electrical wiring.

7. Apparatus according to Claim 4 or 5, wherein the or each side passage is provided with a collection chamber for filtrates and sewage, a pump and discharge conduit being provided for discharging the contents thereof to the surface.

8. Apparatus according to Claim 1, 2 or 3, which is intended to be of relatively high capacity, independent well bores defining the saline water feed conduit and brine discharge conduit, a third well bore communicating with the atmosphere affording access to an underground chamber containing the osmosis cells for delivery of fresh water and access of pipes and services.

9. Apparatus according to Claim 1, 2 or 3, which is of relatively low capacity and comprises a single well shaft fed through its mouth with saline water and a submerged osmotic cell or cells connected to the surface through an umbilical pipe containing within it the riser pipes for brine and desalinated water and which communicates the fresh water sides of the osmotic cell or cells with atmospheric pressure.

10. Apparatus for desalinating water by reverse osmosis substantially as hereinbefore described with reference to and as illustrated in Figure 1, or in Figures 2, 3 and 4 of the accompanying drawings.

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